# Accumulation and Headloss Calculations

**Gilbert Zigler**
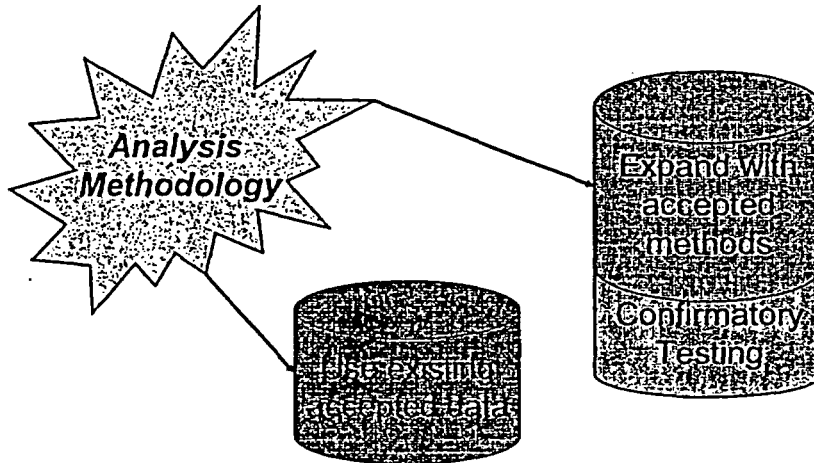**Alion Science and Technology**
**ITS Operations**

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# Overview

- Inputs to Head Loss Evaluation
- Head Loss Calculation Methodology
- Uncertainties
- Summary

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## Head Loss Calculation Methodology



*Analysis Methodology*

Expand with accepted methods

Confirmatory Testing

Use existing accepted data

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## Total Head Loss

**Total Head Loss =**
**Clean Strainer Head Loss +**
**Debris Bed Head Loss**

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# Debris Bed Head Loss

- Fibrous Debris Bed Head Loss
  *NUREG/CR-6224 Head Loss Correlation*

- RMI Debris Bed Head Loss
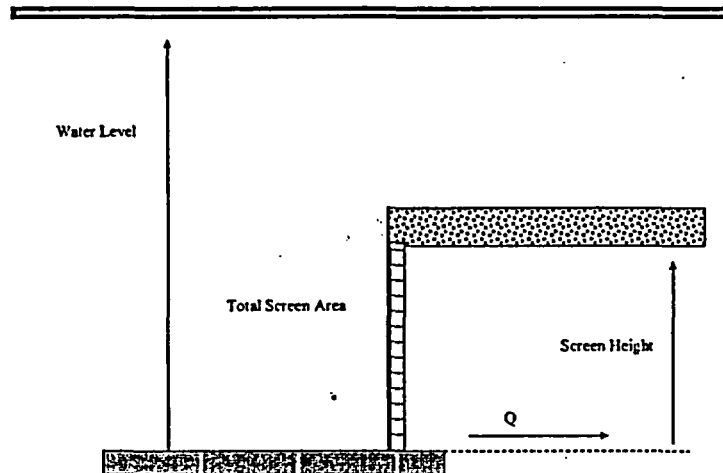  *NUREG/CR-6808 RMI Head Loss Correlation*

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# Inputs

- Sump Screen Geometry

- Thermal-Hydraulic Conditions

- Debris Accumulation

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# Sump Key Parameters

Water Level

Total Screen Area

Screen Height

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# Sump Screen Submergence

- Fully Submerged Screens
  - Ambient Pressure Present on One Side of the Screen
  - Flow Driver is the Pump Suction

- Partially Submerged Screens
  - Ambient Pressure Present on Both Sides of the Screen
  - Flow Driver is the Difference in Fluid Elevation Between the Sides of the Screen

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# Success Criteria

- Fully Submerged Screen

  *Clean + Debris Bed < $NPSH_{available}$*

- Partially Submerged Screen

  *Clean + Debris Bed < ½ Screen Submergence Height*

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# Thermal-Hydraulic Conditions

- Recirculation Pool Water Level
- ECCS Flow Rate
- Recirculation Pool Water Temperature
- Recirculation Pool Water Chemistry
- ECCS Recirculation Mission Duration

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# Debris Accumulation

- Containment Flow Restrictions

- Sump Screen Assumptions
  - Flat Plates
  - Uniform Debris Deposition

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# Debris Bed Characteristics

- Insulation Debris Characteristics
  - Macroscopic Density – As Fabricated
  - Microscopic Density – Material
  - Fiber Diameter
- Failed Coatings Characteristics
  - In ZOI
  - Outside ZOI
- Miscellaneous Debris Characteristics

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| Debris Name | Insulation Material Description | As-Fabricated Density (lbs/ft³) | Material Density (lbm/ft³) | Characteristic Size | |
|---|---|---|---|---|---|
| | | | | μm | inch |
| PCI's NUKON® Blankets | Removable / reusable blankets with woven glass fiber cloth covering fibrous glass insulating board (referred to by the NRC as a "LDFG") | 2.4[5,7] | 159[7] | 7.0 fiber diameter | 28E-05[5,7] |
| Fiberglass – preformed pipe | Knaupf fibrous glass wool preformed into cylindrical shapes | 4.0 +/- 10%[2] or | 159[2] | 7.5 fiber diameter | 30E-05[2] |
| Fiberglass – preformed pipe | Owens-Corning fibrous glass wool preformed into cylindrical shapes | 3.5 to 5.5[7] | 159[7] | 8.25 fiber diameter | 33E-03[7] |
| Fiberglass – pipe and tank wrap | Fibrous glass wool wrap, using perpendicularly oriented fibers, adhered to an All Service Jacketing (ASJ) facing (made by Knaupf, Owens-Corning, & others) | 3.0 +/- 10% | 159[2] | 6.75 fiber diameter | 27E-05[2] |
| Transco's Thermal Wrap® Blankets | Removable / reusable blankets with woven glass fiber cloth covering fibrous glass insulant ) | 2.4[2,14] | 159[2] | 5.5 fiber diameter | 22E-05[2] |
| Knaupf | Knaupf ET Panel (LDFG similar to Nukon) | 2.4 | 159 | 5.5 fiber diameter | 22E-05 |
| Temp-Mat® and Insulbatte® | Glass fibers needled into a felt mat: these are trade names of insulation products made by JPS Corp. | 11.8[4] | 162[4] | 9.0 fiber diameter | 36E-05 max. average[15] |

| Cellular Glass | Foamglas® is the trade name for this cellular glass product made by Pittsburgh Corning Corporation | 6.1 to 9.8 (mean value of 7.5)[15] | 156[15] | NA | 0.05 to 0.08 pore size[17]: grain size unknown |
|---|---|---|---|---|---|
| Kaowool® | Needled insulation mat made from ceramic fibers; Kaowool is a trade name for a family of ceramic fiber products made by Thermal Ceramics, Inc. | 3 to 12[6] | 160 to 161[16] | 2.7 to 3.0[16] fiber diameter | 10.8 to 12.0E-05 |
| Cerawool® | Needled insulation mat made from ceramic fibers; Cerawool is a trade name for a family of ceramic fiber products made by Thermal Ceramics, Inc. | 3 to 12[6] | 156 to 158[16] | 3.2 to 3.5[16] fiber diameter | 12.8 to 14.0E-05 |
| Mineral Wool | Generic name for families of products made by Rock Wool Mfg., Roxul, Fibrex, IIG, and others | 4, 6, 8, and 10[5] pcf are standard | 90[5] | 5 to 7[5] fiber diameter | 20 to 28 E-05 |
| MinK® | Trade name of microporous insulation products made by Thermal Ceramics, Inc. from fumed silica, glass fibers, and quartz fibers | 8 to 16 pcf[7] | NA | < 0.1[18] | < 4E-06 |
| Calcium Silicate | Manufactured by IIG in three locations (2 use diatomaceous earth, 1 uses expanded perlite) | 14.5[9] | 144[10] | 40 μm mean particle size (2 to 100 μm range)[16] | 1.60E-03 |
| Microtherm | Microporous Insulation | 5 to 12 pcf | NA | <0.2 | <4.0E-06 |
| Asbestos | Structural fiber used in Cal-Sil type ins. | 7 to 10 | 153 | 1 to 8 | 4 to 32E-05 |

# Fiber



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# Head Loss Calculations

- NUREG/CR-6224 Correlation
- NRC SER RMI Correlation
- Mixed Fiber + RMI Debris Beds
- Microporous Materials

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# NUREG/CR-6224 Correlation

$$\Delta H = \Lambda \, [3.5 \, S_v^2 \, \alpha_m^{\,1.5} \, (1+57 \, \alpha_m^3) \, \mu \, U +$$
$$0.66 \, S_v \, \alpha_m/(1-\alpha_m) \, \rho \, U^2 \,] \, \Delta L_m$$

- Account for Compression
- Average Surface to Volume Ratio

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# NUREG/CR-6224 Correlation
### (Cont.)

- Semi-Theoretical Correlation
  - Allows for use of other materials and conditions beyond those tested
- Flat Plate Geometry
  - Uniform Debris Accumulation
  - Applicable to both submerged and partially submerged screens
- Alternate Geometry Screens

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# Thin Bed Effect

- A Fiber Debris Bed ~ 1/8 in. thick filters particulates efficiently
- For High Particulate Loads a Thin Fiber Bed Could Trap Particulates on its Surface to Form a Layer of "Mud"
- Particulate Layer has Low Porosity
  - ➢ High Head Losses

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# Typical Fiber + Particulate Head Loss Estimates



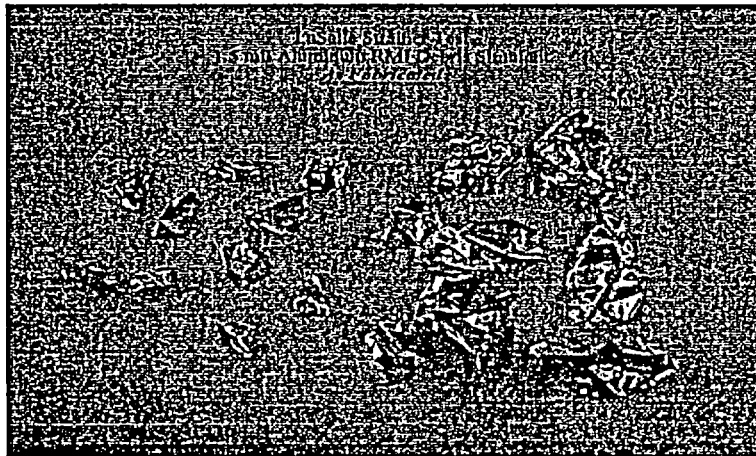**ECCS Flow: 2,500 gpm**
**Dirt/Dust: 100 lbs**

Head Loss - ft. of water

Fibrous Debris (cu ft)

———100 sq ft     ——···600 sq ft     ———2000 sq ft
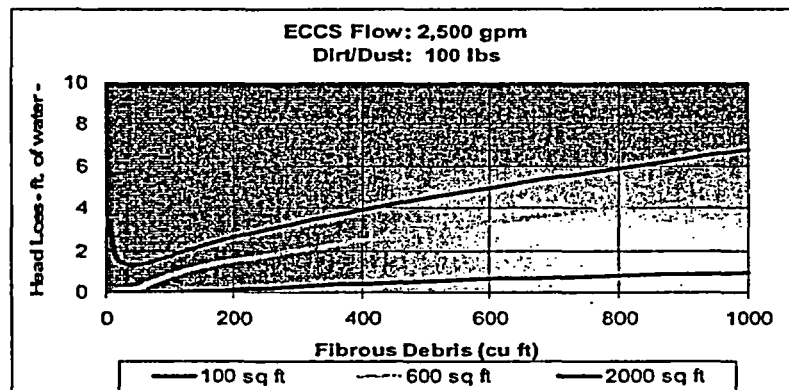
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# RMI Correlation

- NUREG/CR-6808 RMI Correlation

$$\Delta H = 0.108 \ U^2 \ A_{foil}/A$$

- Bounds the Available Data hence Independent of RMI Debris Size & Type

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# Typical RMI Debris



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# Mixed RMI + Fiber Debris Beds

- Mixed RMI and Fibrous Debris Beds:

$$\Delta H_{(total)} = \Delta H_{RMI} + \Delta H_{fiber + particulate}$$

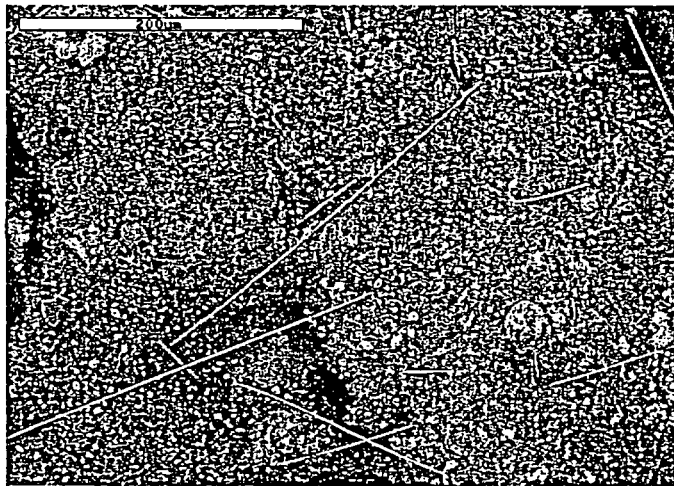- Potentially overly-conservative for high RMI to fiber ratios.

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# Mixed RMI + Fiber



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# Microporous Debris

- Limited Experimental Data on Microporous Debris

- Upcoming Reports and NUREGs of NRC Experiments Reported Earlier This Year

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# Calcium Silicate



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## Mixtures of Microporous & Fibrous Debris

The NUREG/CR-6224 head loss model conservatively estimates head losses for microporous-to-fiber ratios (by weight) *less* than 0.2

- Microporous insulation modeled as spherical particulate with a nominal diameter of 5 µm and a microscopic density of 140 lb/ft³
- Visual observations of the debris bed showed microporous insulation dispersed throughout the fibers as individual amorphous particulates
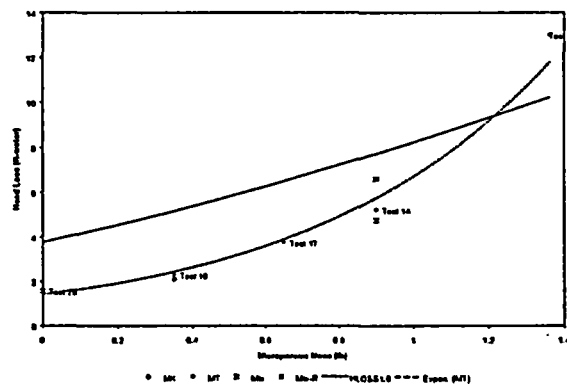
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## Mixed Microporous & Fibrous Debris
## Low Microporous/Fiber Ratio
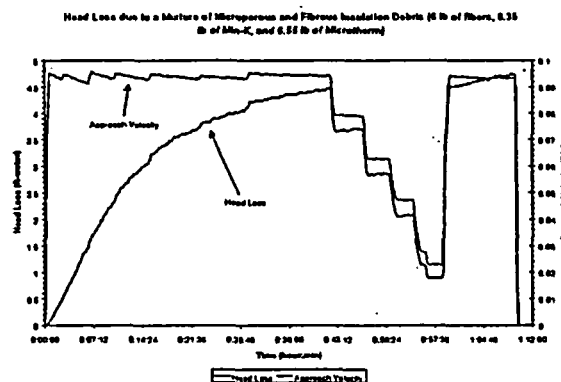


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## Comparison of NUREG/CR-6224 Head Loss Correlation
## Mixed Microporous and Fibrous Debris Beds



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# Mixtures of Microporous & Fibrous Debris

Significantly high head losses *not predictable* by the
NUREG/CR-6224 model were observed for
microporous-to-fiber ratios (by weight) _more_ than 0.2

- the microporous constituents in mixed debris beds of
  microporous-to-fiber ratios (by weight) greater than 0.2
  undergo a change in the morphology of the microporous debris
  materials - the amorphous particulate agglomerates to form a
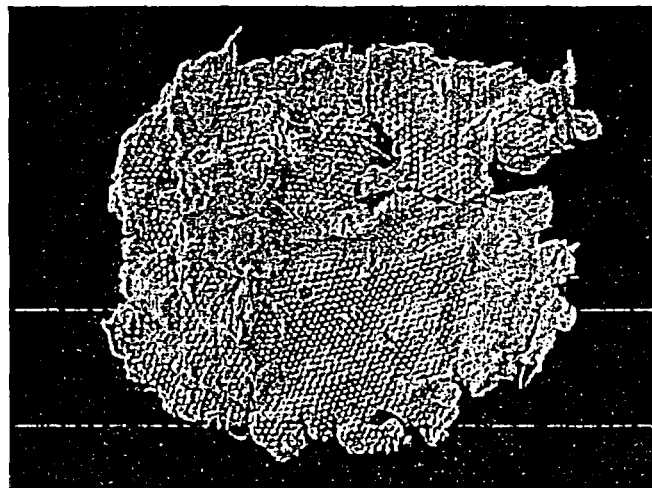  film that evolves into an impervious plaque.

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## Mixed Microporous & Fibrous Debris
## High Microporous/Fiber Ratio
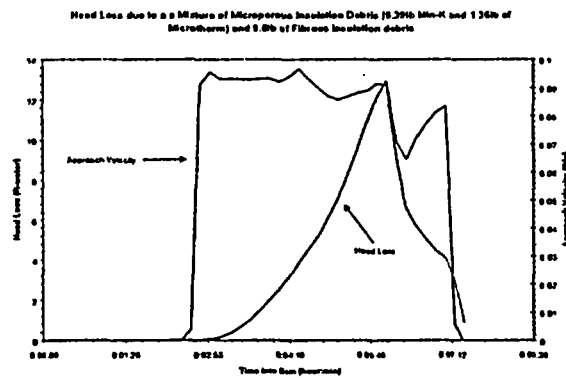


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## High Microporous to Fiber Ratio
## Debris Bed



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## SEM of High Microporous to Fiber Ratio Debris Bed



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## Summary

Experimentally Based Bounding Correlations to Determine Head Loss Calculations:

- NUREG/CR-6224 Correlation for Fibrous Beds
- NUREG/CR-6808 RMI Correlation

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